General Characteristics		
1	**Abstract of Model Capabilities**	MATHEW/ADPIC are the core codes for the DOE Atmospheric Release Advisory Capability (ARAC) program at Lawrence Livermore National Laboratory (LLNL), Livermore, Calif. The models are used to simulate dispersion from a wide variety of releases of hazardous material in the atmosphere. The ARAC models can be used to make both real-time responses as well as assessments of radiological or chemical releases using sequential time-varying meteorological and source term inputs. The diagnostic models are applicable to all mesoscale meteorological and topographic settings (domain of a few km to thousands of km). The ARAC Model Set consists of the following 6 codes which are available in the public domain version: TOPOG - Topographic grid generation code MEDIC - Meteorological data interpolation code CG-MATHEW - Conjugate-Gradient Mass-Adjusted Three-Dimensional Wind Field ADPIC - Atmospheric Dispersion by Particle-in-Cell PLCNT - A graphical contour plot generator TIMHIS - A Time History statistical analysis of ADPIC output values at individual receptors with optional comparison with measurement data. Several databases and programs to automatically initialize each of the 6 codes reside on the LLNL ARAC system, but are not included in the public domain version. These include terrain, geography, model parameter, default sources, chemical properties, dose conversion factors, chemical and radiological consequence guideline databases, a chemical source model, and real-time meteorological data feeds.
2	**Sponsor and/or Developing Organization**	Sponsor: US Department of Energy (DOE) Developer: Lawrence Livermore National Laboratory (LLNL) Distributor: US DOE Energy Science and Technology Software Center (ESTSC) Office of Emergency Response (DP-23) US DOE 10001 Germantown Road Washington, DC 20585 (301) 903-3558 (301) 903-6417 **Fax** ARAC Program Manager LLNL Mail Code L-103 P.O. Box 808 Livermore, CA 94550 (925) 422-1801 (925-423-5167 **Fax** DOE Energy Science and Technology Software Center (ESTSC) P.O. Box 1020 Oak Ridge, TN 27831 estc@adonis.osti.gov web: http://apollo.osti.gov/html/osti/estsc/estsc.html ESTSC Package ID Number: ESTC--000279D0VAX02
3	**Last Custodian/ Point of Contact**	Hoyt Walker, Connee Foster LLNL Mail Code L-103 P.O. Box 808 Livermore, CA 94551-0808 walker7@llnl.gov **primary individual** foster2@llnll.gov **secondary individual**
4	**Life-Cycle**	The MATHEW/ADPIC models were initially developed at LLNL in the mid-1970s as the basis for the Atmospheric Release Advisory Capability (ARAC) emergency response system. The initial version of the ARAC system (ARAC-1) became operational shortly before the Three Mile Island incident in 1979. From 1982-1985, the entire system was reengineered to run on DEC-VAX to support acquisition of global meteorological, topographic, and geographic data (ARAC-2). The ARAC-2 models underwent a major restructuring in the early 1990s. In 1994, MATHEW's numerical method and handling of boundary conditions were greatly improved (CG-MATHEW). In 1995, the ADPIC dispersion code was extended to include a cell-independent, purely Lagrangian Monte Carlo approach to modeling diffusion. CG-MATHEW/ADPIC Version 5.0 was frozen for public release in February, 1997. In 1996, LLNL began building the third generation system (ARAC-3). The MATHEW/ADPIC models will be replaced with new diagnostic meteorological (Atmospheric Data Assimilation and Parameterization Techniques-ADAPT) model and a new Lagrangian dispersion (Livermore Operational Dispersion Integrator-LODI) model that have a continuous terrain representation, variable 3-Dimensional grids, and prognostic model inputs. The system is being re-engineered to be independent of operating system, use of third-party software, and have a fully graphical user interface.

5	**Model Description Summary**	A typical run stream for the ARAC dispersion model set involves a sequence of 5 codes: TOPOG, MEDIC, MATHEW, ADPIC, and PLCNT. TOPOG produces a Eulerian grid of block-form terrain cell heights for the lower boundary of the model system. Meteorological observations or gridded data are input into MEDIC which performs an initial inverse-distance-squared weighting interpolation over the grid using. CG-MATHEW generates a mass-consistent wind field by a minimal adjustment of the interpolated MEDIC wind field. CG-MATHEW adjusts wind vectors using a finite-difference stencil for the Poisson equation and a conjugate gradient solution of the Euler-Lagrange equations. Vertical velocities are generated by enforcing the continuity equation on each grid cell. Flow either travels over or around or is blocked by terrain according to atmospheric stability. ADPIC provides the dispersion physics for a wide range of emissions, such as neutrally buoyant gases, and/or particles, including radioactive materials and chemicals. Up to 100,000 marker particles are available to represent as many as 9 different sources or species in a single model run. Each source may have its own release rate, particle-size distribution, deposition velocity, and plume-rise characteristics. Sources may be either instantaneous puffs or continuous plumes with any initial point, line, area, or volume geometry and time-varying release rates. First-order chemical, radioactive or ultraviolet light decay, particle-size-dependent gravitational settling, dry deposition, and precipitation scavenging can be computed during each time step for each source. Four inner nested grids with 2, 4, 8, and 16 times the resolution of the primary grid cell provide higher resolution near sources. ADPIC uses the wind fields from CG-MATHEW for the transport component of dispersion. The diffusion component in ADPIC is based on K-theory parameterizations of horizontal and vertical eddy diffusivities. ADPIC solves the advection-diffusion equation using one of two options -- the original hybrid Eulerian-Lagrangian particle-in-cell technique or the newer Random Displacement Method (RDM). RDM, a purely Lagrangian Monte Carlo statistical approach, is the preferred option. PLCNT produces a variety of contoured outputs on geographic map coordinates. Typical model results include plots of material deposited on the ground, instantaneous and time-integrated doses, or air concentrations (instantaneous, time-averaged, integrated, or composite peak over a period) at selected levels above the ground. Species or sources may be combined as required and contoured according to user-specified isopleth values.
6	**Application Limitation**	MATHEWÕs diagnostic wind field is controlled by wind and user inputs. Interpolation of sparse data can be a limitation. ADPIC does not perform chemical transformations.
7	**Strengths/ Limitations**	**Strengths:** The code is very robust and has been applied to thousands of assessments, responses and exercises over a 20-year period. **Limitations:** The model uses a block cell representation of terrain, which can result in limited spatial resolution depending on terrain steepness and the number and size of grid cells used in the domain.
8	**Model References**	! Atmospheric Release Advisory Capability (ARAC) 1997: User's Guide to the CG-MATHEW/ADPIC Models, Version 5.0. ARAC, Lawrence Livermore National Laboratory UCRL-MA-103581 Rev. 5. ! Sugiyama, G., Lee, R.L., and Walker, H., 1994: Conjugate Gradient MATHEW, Lawrence Livermore National Laboratory Report UCRL-ID-118629. ! Ermak, D.L., J.S. Nasstrom, and A.G. Taylor, 1995: Implementation of a Random Displacement Method (RDM) in the ADPIC Model Framework, Lawrence Livermore National Laboratory UCRL-ID-121742. ! Lange, R., 1989: Transferability of a Three-Dimensional Air Quality Model between Two Different Sites in Complex Terrain, *Journal of Applied Meteorology*, Volume 28, pp. 665--679. ! Lange, R., 1978: A Three-Dimensional Particle-in-Cell Model for the Dispersal of Atmospheric Pollutants and Its Comparison to Regional Tracer Studies, *Journal of Applied Meteorology* ,Vol. 17, pp. 320--329.
9	**Input Data/Parameter Requirements**	! Domain and grid cell dimensions along with gridded topographic elevations for each cell. Note: NetCDF (Network Common Data Form), used to store elevation data used by the TOPOG model, is available from the Unidata Program Center web site referenced in the MATHEW/ADPIC Users Guide. ! Meteorological data - Single or multiple surface and upper air observations or gridded analyses or forecast model wind fields sequentially in time for as many user-specified averaging times as desired. ! Time-varying meteorological and dispersion inputs and control parameters to specify atmospheric stability, vertical wind profile interpolation, mixing heights, diffusivity method, number of marker particles per source, source geometry, source location, release rates, particle size distributions, plume rise, deposition velocities. ! Output graphics control, final output unit conversion factors, contour values, and labeling information.

10	**Output Summary**	Each of the six codes produces graphical outputs in the form of GKS graphics files --Topographic cell heights, wind profiles and vector fields, marker particle overhead and cross-section views, and contour isopleth plots. All inputs are also echoed in output files. The user can also produce arrays of output values. Note: The VAX/VMS version includes GKS graphics; no attempt has been made to make this capability work in the UNIX environment. The ARAC-2 models augment the strict definition of GKS graphics and use a particular implementation of a CGM standard for graphics metafiles. Some development effort will be necessary to use the ARAC graphics code. All graphics calls in the source code can be removed with differential compile logic. Unix users may use other graphics packages such as PV-Wave or IDL.
11	**Applications**	MATHEW/ADPIC has been applied to thousands of assessments, safety analyses, responses to accidental releases and emergencies, and exercises throughout the world. Some of the over 80 responses include: ! Material processing and transportation accidents -1986 Sequoyah Fuels Plant UF6 accident, Gore, Oklahoma, several tritium releases ! Nuclear power plant accidents - 1979 Three Mile Island; 1986 Chernobyl ! Nuclear-powered spacecraft - Satellite re-entry*:* 1978 Soviet Cosmos 954, 1996 Russian Mars-96 - NASA missions: 1989 Galileo, 1990 Ulysses, 1997 Cassini ! Nuclear weapons accidents - 1980 Titan II missile accident - Damascas, Arkansas ! Volcanic eruptions - 1989 Mt. Redoubt, Alaska, 1991 Mt. Pinatubo, Philippines ! Desert Storm, Persian Gulf, 1990-91: contingency calculations for chemical SCUDS, nuclear facilities, nuclear weapons, battlefield oil fire smoke obscuration ! Kuwait oil fires, 1991 - daily forecasts of regional opacity ! Industrial chemical accidents - 1991 Metam sodium spill into Sacramento River, Calif. - 1993 Sulfuric acid release from overheated oleum tank car, Richmond, Calif. - 1996 Bogalusa, Louisiana nitrogen tetroxide tank car - 1996 Cajon Pass, Calif. rail accident, multiple chemicals
12	**User-Friendliness**	No graphical user interface is provided for the public version. To create input files the user must edit FORTRAN namelist files. To execute each of the codes the user must enter individual run commands.

13	**Hardware-Software Interface Constraints/ Requirements**	**Computer operating system:** The ARAC-2 CG-MATHEW/ADPIC Version 5.0 set of six codes is available for public distribution via the DOE Energy Science and Technology Software Center (ESTSC) in Oak Ridge, TN. Two versions of the software are provided in separate file groupings -- the native DEC-VMS operating system and a differential compile for UNIX platforms. The VMS grouping has the full sources as they exist in the ARAC system, along with the MMS files used to build different versions of the models on the VMS system. The UNIX version covers the necessary details for installing the models in a UNIX environment. The UNIX versions have been installed under Solaris, Digital UNIX, IRIX and UNICOS. Other Programming or Operating Information or Restrictions: Compiling the source code requires a Fortran-77 compiler with extensions for namelist I/O, long variable names and include files. Graphics output requires a GKS library, although all graphics can be removed via differential compilation. The full package also includes some DEC-Pascal routines but these can also be removed via differential compilation. Memory requirements vary with various compiled parameters such as the grid dimensions. For example, for a MATHEW grid of 51x51x15 and an ADPIC grid of 41x41x15 the codes have the following memory requirements in a VAX/VMS environment: TOPOG - 31 Megabytes MEDIC - 122 Megabytes MATHEW- 19 Megabytes ADPIC - 47 Megabytes PLCNT - 16 Megabytes TIMEHIS - 123 Megabytes **Computer platform:** DEC VAX or any Unix platform **Disk space requirements:** Disk requirements vary with the run time and frequency of graphics, etc. **Run execution time** (for a typical problem)**:** Run time is dependent upon modeling time and several user-selected parameters (such as the number of marker particles used in ADPIC). A typical one-hour simulation (TOPOG through PLCNT) using 5000 marker particles completes in less than 2 CPU minutes on a VAX 6610. **Programming** language: FORTRAN, Pascal **Other computer peripheral information:** No information provided.
14	**Operational Parameters**	**Identify whether the code has any error diagnostic messages to assist the user in troubleshooting operational problems:** Range checking and some input error diagnostics are available. There are limited run-time diagnostics; FORTRAN trace-back error statements are the basic method for determining model crashes. **Set up time for: Typical times are:** ***first-time user:*** VAX-VMS version 2-3 months Unix version: 1 month ***experienced user:*** VAX-VMS version: 1 month Unix version: a few days, especially on Sun workstation under Solaris operating system

<table>
<tr><td>15</td><td>Surety Considerations</td><td>
All quality assurance documentation: Atmospheric Release Advisory Capability (ARAC) 1997: Users Guide to the CG-MATHEW/ADPIC Models, Version 5.0. ARAC, Lawrence Livermore National Laboratory UCRL-MA-103581 Rev. 5.
Sugiyama, G., Lee, R.L., and Walker, H., 1994: Conjugate Gradient MATHEW, Lawrence Livermore National Laboratory Report UCRL-ID-118629.
Ermak, D.L., J.S. Nasstrom, and A.G. Taylor, 1995: Implementation of a Random Displacement Method (RDM) in the ADPIC Model Framework, Lawrence Livermore National Laboratory UCRL-ID-121742. The codes have been run many thousands of times. Each new update is documented and tested before implemented. Over 1000 software change requests for revisions or fixes have been resolved through a formal system of prioritization, documentation and tracking.
Benchmark runs: In addition to testing the wind field against a potential flow field around a semi-hemispheric hill, the following 6 field tracer experiments are used to statistically benchmark model improvements:
<table>
<tr><td>Sponsor</td><td>Project-Location</td><td>Date</td></tr>
<tr><td>USAF</td><td>Project Prairie Grass, O'NEILL, NB</td><td>1957</td></tr>
<tr><td>AEC</td><td>Roller Coaster (explosions), NTS, NV</td><td>1963</td></tr>
<tr><td>EPRI</td><td>Plume Model Validation - Kincaid, IL</td><td>1980Ð1</td></tr>
<tr><td>DOE</td><td>MATS-Savannah River Plant, SC</td><td>1983</td></tr>
<tr><td>PG&E</td><td>DOPPTEX - Diablo Canyon NPP, CA</td><td>1986</td></tr>
<tr><td>CEC-IAEA-WMO</td><td>ATMES (Chernobyl)</td><td>1991</td></tr>
</table>
Validation calculations: Validation is achieved based on a significant number of model verifications or evaluations; see below.
Verification with field experiments that has been performed with respect to this code: The model has been evaluated against hundreds of tracer data sets from over 20 field programs in a wide variety of settings and scales from a few to thousands of km.
<table>
<tr><td>Sponsor</td><td>Project-Location</td><td>Date</td></tr>
<tr><td>Up to 100 km</td><td></td><td></td></tr>
<tr><td>USAF</td><td>Project Prairie Grass, O'NEILL, NB</td><td>1957</td></tr>
<tr><td>AEC</td><td>Roller Coaster (explosions), NTS, NV</td><td>1963</td></tr>
<tr><td>NOAA</td><td>I-131 - Idaho Natl. Engr. Lab, ID</td><td>1971</td></tr>
<tr><td>DOE</td><td>Ar-41 - Savannah River Plant, SC</td><td>1974</td></tr>
<tr><td>Rise¿</td><td>Copenhagen, Denmark</td><td>1978-9</td></tr>
<tr><td>DOE</td><td>TMI Kr-85 Purge - Harrisburg, PA</td><td>1980</td></tr>
<tr><td>EPRI</td><td>Plume Model Validation - Kincaid, IL</td><td>1980Ð1</td></tr>
<tr><td>DOE</td><td>ASCOT - Geysers Geothermal Area, CA</td><td>1980</td></tr>
<tr><td>DOE</td><td>ASCOT - Geysers Geothermal Area, CA</td><td>1981</td></tr>
<tr><td>DOE</td><td>MATS-Savannah River Plant, SC</td><td>1983</td></tr>
<tr><td>ENEL</td><td>Montalto NPP, Italy</td><td>1984</td></tr>
<tr><td>DOE</td><td>ASCOT - Brush Creek, CO</td><td>1984</td></tr>
<tr><td>Rise¿</td><td>¯resund Strait, Sweden-Denmark</td><td>1984</td></tr>
<tr><td>PG&E</td><td>DOPPTEX - Diablo Canyon NPP, CA</td><td>1986</td></tr>
<tr><td>NILU</td><td>Lillestr¿m, Norway</td><td>1987</td></tr>
<tr><td>DOE</td><td>STABLE - Savannah River Plant, SC</td><td>1989</td></tr>
<tr><td>DOE</td><td>ASCOT - Rocky Flats Plant, CO</td><td>1991</td></tr>
<tr><td>Up to 1000 km</td><td></td><td></td></tr>
<tr><td>CARB</td><td>San Joaquin Valley AQ Study, CA</td><td>1990</td></tr>
<tr><td>Up to 5000 km</td><td></td><td></td></tr>
<tr><td>NOAA</td><td>CAPTEX</td><td>1983</td></tr>
<tr><td>NOAA</td><td>ANATEX</td><td>1987</td></tr>
<tr><td>DOE</td><td>Semipalatinsk, Russia</td><td>1987</td></tr>
<tr><td>CEC-IAEA-WMO</td><td>ATMES (Chernobyl)</td><td>1991</td></tr>
<tr><td>CEC-IAEA-WMO</td><td>ETEX</td><td>1994-6</td></tr>
</table>
See: Sullivan, T.J., J.S. Ellis, C.S. Foster, K.T. Foster, R.L. Baskett, J.S. Nasstrom, and W.W. Schalk, III, 1993: Atmospheric Release Advisory Capability: Real-Time Modeling of Airborne Hazardous Materials, <i>Bulletin of the American Meteorological Society</i>, Vol. 74, No. 12, December 1993, Boston, MA.
</td></tr>
<tr><td>16</td><td>Runtime Characteristics</td><td>A typical one-hour simulation (TOPOG through PLCNT) using 5000 marker particles completes in less than 2 CPU minutes on a VAX 6610.</td></tr>
<tr><td colspan="3">Specific Characteristics</td></tr>
<tr><td colspan="3">Part A: Source Term Submodel Type</td></tr>
<tr><td>A1</td><td>Source Term Algorithm?</td><td>_✔_YES __NO</td></tr>
</table>

A2	**For Chemical Consequence Assessment Models**	**Liquid spill: _✔ pool evaporation _✔ particulate resuspension** Any type of chemical release can be specified using ADPIC source parameters. Physical property data on chemicals and source term models do not come with the public domain source code. **Pressurized releases:__ two-phase jets__ flashing__ entrainment__ aerosol formation** **Solid spills: _ resuspension _ sublimation**
A3	**For Radiological Consequence Assessment Models**	**Gaseous releases: _✔_ noble gases _✔_ iodines _✔_ other non-reactive gases** - Radioactive decay and ingrowth of single or multiple isotopes - Any gas or particulate isotope **-** Tritium User specifies initial 3-D source geometry, source location (UTM coordinates), and time-varying source rate in any user-specified unit, e.g., g/sec or Ci/sec, for up to 9 sources or nuclides. **Aerosol releases:** - Log-normal or clipped log-normal mass size distributions. **Particulate releases:** - Log-normal or clipped log-normal mass size distributions. **_✔_ Chemistry __ Isotopic exchange __ Physical properties capability** First-order decay.
A4	**For Weapons Consequence Assessment Models**	**Chemical weapon release characteristics:** Any type of chemical weapon release can be specified using ADPIC source parameters. Data on weapons does not come with the public domain source code. **Biological weapon release characteristics:**
Part B: Dispersion Submodel Type		
B1	**Gaussian**	**__Straight-line plume __Segmented plume __ Statistical plume __ Statistical puff**
B2	**Similarity**	**_✔_ Plume _✔_ Puff**
B3	**Stochastic**	**_✔__ Monte Carlo _✔__ Random walk**
B4	**Gradient Transport or K-Theory**	ADPIC is based on K-theory parameterizations of horizontal and vertical eddy diffusivities -- similarity theory for vertical diffusivity and horizontal diffusivity from sigma theta inputs and DraxlerÕs (1976) parameterization. Draxler, R.R., 1976: Determination of atmospheric diffusion parameters. *Atmospheric Environment*, Vol. **10**, pp. 99Ð105.
B5	**Particle-In-Cell**	The original ADPIC Eulerian-Lagrangian particle-in-cell technique has been replaced with a newer, preferred, purely Lagrangian Random Displacement Method (RDM) (See Item 8 below)
B8	**Particle**	ADPIC (Atmospheric Dispersion by Particle-in-Cell) is a numerical, 3-D particle-diffusion code which calculates the time-dependent distribution of air pollutants under many conditions including distorted wind fields, calm conditions, wet and dry deposition, radioactive decay, and space- and time-variable turbulence parameters. ADPIC solves the advection-diffusion equation using one of two options -- the original Eulerian-Lagrangian particle-in-cell technique or the newer Random Displacement Method (RDM). RDM, a purely Lagrangian Monte Carlo statistical approach, is the preferred option.
Part C: Transport Submodel Type		
C1	**Prognostic**	CG-MATHEW can produce prognostic results if the wind fields supplied to MEDIC are from another prognostic model.
C2	**Deterministic**	Two codes, MEDIC and CG-MATHEW, are used to create a transport wind field from either observations or gridded wind inputs. The user may input single or multiple surface and upper air observational data or gridded analyses or prognostic model data into MEDIC for each user-specified averaging time. Three separate layers of the atmosphere (surface, boundary, and geostropic) are used to construct the 3-D wind field. The surface layer is the lowest layer in which surface effects predominate and no direction shear with height is allowed. The boundary layer is the region where both speed and directional shear can occur between the surface and geostrophic layers. The highest layer, the geostrophic layer, is the region of the atmosphere where surface effects have disappeared and the winds reflect larger-scale synoptic flow. MEDIC initially interpolates the data over the grid using an inverse-distance-squared weighting. The user controls the influence of meteorological input data on the vertical interpolation in the boundary layer. In

C2	**Deterministic (Cont.)**	sparse data regions, interpolation controlled by power-law profiles is preferred whereas in more dense data regions, extrapolating the input data is preferred. CG-MATHEW generates a 3-D mass-consistent wind field by a minimal adjustment of the purely horizontal (2-D) wind field supplied by MEDIC. A functional is formulated which minimizes the variance between input and output winds subject to a non-divergence constraint, mass-flow boundary conditions on lateral and top faces, and the requirement of zero normal wind-field components at terrain surfaces. The requirement of minimal adjustment maintains consistency with available meteorological measurements, while atmospheric stability governs the relative amounts of change in the vertical and horizontal wind components. The adjustment is irrational and neither momentum balance nor energy conservation is imposed. Velocity components are defined on staggered grid faces so that the mass-consistency constraint is cell-flux rather than grid-point based. The problem then reduces to the solution of the Poisson equation in the Lagrange multiplier, with the adjusted winds derived from the corresponding Euler-Lagrange equations.
C4	**Frame of Reference**	**_✔_ Eulerian __ Lagrangian __ Hybrid __ Eulerian-Lagrangian**
Part D: Fire Submodel Type (Not Applicable)		
Part E: Energetic Events Submodel Type		
E2	**Dust Explosions**	Not explicitly treated, but may be simulated with an initial mushroom-shaped fixed source geometry.
E3	**Deflagrations**	Not explicitly treated, but may be simulated with an initial mushroom-shaped fixed source geometry.
E4	**Detonations**	Two options are available: ! An initial mushroom-shaped fixed source geometry. ! A time-dependent explosive cloud rise module. The explosive cloud rise submodel in ADPIC provides a time evolution of the physical and thermodynamic properties of a buoyant cloud formed when a chemical explosive is detonated. This module generates additional vertical and horizontal components of motion applied to each ADPIC marker particle while under the influence of the rising thermal from the detonation. The code is based on integrating the 3-D conservation equations of mass, momentum, and energy over the cloud's cross section. With some simplifying assumptions the integral equations reduce to a set of ordinary differential equations which can be solved for the cloud radius, centerline height, temperature, and velocity as a function of time. The code is patterned after Boughton and Delaurentis (1987) with implementation details in Foster, *et. al.* (1990). Boughton, B.A., J.M. Delaurentis, and W.E. Dunn 1987: A stochastic model of particle dispersion in the atmosphere, *Boundary-Layer Meteorology*, Vol. **40**, pp. 147-163. Foster, K.T., R. Freis, J.S. Nasstrom, 1990: Incorporation of an explosive cloud rise code into ARAC's ADPIC transport and diffusion model. Lawrence Livermore National Laboratory Report UCRL-ID-103443.
E5	**Vapor Cloud Explosions**	Not explicitly treated, but may be simulated with an initial mushroom-shaped fixed source geometry.
E6	**Boiling Liquid Expanding Vapor Explosions (BLEVEs)**	Not explicitly treated, but may be simulated with an initial mushroom-shaped fixed source geometry.
E7	**Missile Generation**	Not explicitly treated, but may be simulated with an initial mushroom-shaped fixed source geometry.
E8	**High Explosives**	See Item number 4.

E9	**Nuclear Detonations**	Not treated.

Part F: Health Consequence Submodel Type

F1	**For Chemical Consequence Assessment Models**	**Health effects: __ fatalities __ cancers __ latent cancers __ symptom onset** The user can specify any conversion factor in PLCNT to convert the source units and averaging/integration time in ADPIC to any desired contour plotting units, including those below. **Health criteria** **✓ IDLH ✓ STEL ✓ TLV ✓ TWA** **✓ ERPG ✓ TEEL ✓ AEGL ✓ WHO** **Zones with flammable limits: __ UFL __ LFL** **Blast overpressure regions:** **Fire radiant energy zones:** **Risk qualification:** **Concentration: ✓ single value ✓ time-history ✓ integrated dose** **Probits:**
F2	**For Radiological Consequence Assessment Models**	**Cloudshine: __ finite cloud ✓ semi-finite cloud __ other** **Groundshine: ✓ short-term ✓ long-term** **Inhalation: ✓ short-term ✓ long-term** **✓ Total effective dose equivalent** **✓ Uptake of respirable fraction of particle spectra** **Resuspension: ✓ short-term _ long-term__ Anspaugh** User can specify a deposition pattern as an area source for resuspension. **Food/Water Ingestion: __ dynamic _ static** **Skin dose: __ absorption _ other**-0070. **Dose assessment: ✓ ICRP-60 criteria ✓ organs ✓ pathways** The databases for the following are not included in the public domain version of the code. However the user may specify any health criteria on the contours provided an appropriate air concentration bin has been set up in ADPIC. **Health effects: ✓ early _ latent**
F3	**For Weapons Consequence Assessment Models**	**Health effects: __ fatalities __ cancers __ latent cancers __ symptom onset** **Health criteria** **✓ IDLH ✓ STEL ✓ TLV ✓ TWA** **✓ ERPG ✓ TEEL ✓ AEGL** **Risk quantification:** **Concentration: ✓ single value ✓ time-history ✓ integrated dose** **Probits:**

Part G: Effects and Countermeasures Submodel Type (No Information Provided.)

Part H: Physical Features of Model

H1	**Stability Classification Turbulence Typing**	**Pasquill-Gifford-Turner:** User can specify. **STAR:** **Irwin:** **Sigma theta:** Input to ADPIC used to determine horizontal diffusivities. **Richardson number:** **Monin-Obukhov length:** **TKE-driven:** **Split sigma:** ADPIC determines horizontal and vertical diffusivities independently based on similarity laws and empirical equations.
H2	**Release Elevation**	**✓ ground ✓ roof**
H3	**Aerodynamic Effects from Buildings and Obstacles**	**✓ building wake __ cavity __ K-factors __ flow separation** Sources can be released into building wake volumes.
H4	**Horizontal Plume Meander**	Incorporated into an option for stable conditions.
H5	**Horizontal/ Vertical Wind Shear:**	As interpolated and adjusted from observations or gridded vertical profile data.

H6	**Mixing Layer**	**✔ trapping ✔ lofting ✔ reflection ✔ penetration** **✔ inversion breakup fumigation ✔ temporal variability**
H7	**Cloud Buoyancy**	**✔ neutral [passive]** **✔ dense [negative]** The denser-than-air SLAB code is embedded in ADPIC. The user can specify a single steady-state run of SLAB, which will use the nearest surface wind vector from CG-MATHEW at the time and location of the release. **✔ plume rise [positive]** Plume parameterizations rely primarily on Briggs (1975) except for the unstable cases where Weil and Hoult (1973) is used. Separate plume rise equations are used for the various combinations of momentum and buoyancy plume rise, vertical and bent-over plumes, and stability class. Briggs, G.A., 1975: Plume rise predictions. Lectures on Air Pollution and Environmental Impact Analyses (Ed. Haugen), *American Meteorological Society*, pp. 53Ð111, Boston MA. Weil, J.C. and D.P. Hoult, 1973: A correlation of ground level concentrations of sulfur dioxide downwind of the keystone stacks. *Atmospheric Environment*, Vol. **7**, pp. 707Ð721.
H10	**Deposition**	**✔ gravitational setting ✔ dry deposition __ precipitation scavenging** **__ resistance theory deposition ✔ simple deposition velocity ✔ liquid deposition** **__ plateout and re-evaporation**
H11	**Resuspension**	The user can specify a deposited area source as a resuspension source.
H12	**Radionuclide Ingrowth and Decay**	Yes.
H13	**Temporally and Spatially Variant Mesoscale Processes**	**Urban heat island:** As diagnosed from observations. **Canopies:** **Complex terrain (land) effects: __ mountain-valley wind reversals** **__ anabatic winds __ katabaic winds** **Complex terrain (land-water) effects: __ seabreeze airflow trajectory reversals** **__ Thermally Induced Boundary Layer definition __ seabreeze fumigation** **__ landbreeze fumigation** **Thunderstorm outflow:** **Temporally variant winds:** **High velocity wind phenomena: __ tornado __ hurricane __ supercane __ microburst**
Part I: Model Input Requirements		
I1	**Radio(chemical) and Weapon Release Parameters**	**Release rate: ✔ Continuous ✔ Time dependent ✔ Instantaneous** **Release container characteristics: __ vapor temperature __ tank diameter** **__ tank height __ tank temperature __ tank pressure __ nozzle diameter** **__ pipe length** (The ARAC chemical source model which uses container characteristics to model source terms is not included in the public domain codes.) **Jet release: ✔ initial size ✔ shape** **__ concentration profile at end of jet affected zone** **Release dimensions: ✔ point ✔ line ✔ area** **Release elevation: ✔ ground ✔ roof ✔ stack**

I2	**Meteorological Parameters**	**Wind speed and wind direction: ✔ single point __ single tower/multiple point ✔ multiple towers** **Temperature: ✔ single point ✔ single tower/multiple point ✔ multiple towers** **Dew point temperature: __ single point __ single tower/multiple point __ multiple towers** **Precipitation: ✔ single point ✔ single tower/multiple point ✔ multiple towers** **Turbulence typing parameters: __ temperature difference ✔ sigma theta ✔ sigma phi ✔ Monin-Obukhov length ✔ roughness length ✔ cloud cover ✔ incoming solar radiation ✔ user-specified** **Four dimensional meteorological fields from prognostic model:** MEDIC accepts wind fields from any prognostic model.
Part J: Model Output Capabilities		
J1	**Hazard Zone**	User specified contours.
J2	**Graphic Contours and Resolution**	Yes. Resolution depends on model grid and location of 4 inner grid nests, each of which are half the horizontal dimension of the specified grid cell.
J3	**Concentration Versus Time Plots**	Yes
J4	**Tabular at Fixed Downwind Locations**	Yes
J5	**Health Effects**	**✔ toxicity indices [e.g., ERPG's, PAG's] __ potential fatalities __ cancers __ other adverse effects**
J6	**Number of People Affected, Calculated at What Resolution?**	**__ block __ block group __ country** Not provided with public domain codes, but can be incorporated.
J9	**Commerical Off-the-Shelf (COTS) Geographic Information System (GIS) Used**	Not provided with public domain codes, but can be incorporated.
J11	**Accuracy of Output, Calculated in Terms of Percentages of Population Impacted More Than Predicted at one, two, and three Standard Deviations in Urban and Rural Areas**	Accuracy of model output is summarized in ARAC model evaluation papers. The models have been evaluated in both urban and rural areas. One common statistic used in these evaluations is the ratio of observed to modeled concentrations. Results of many model calculations paired in space and time with all available observations show that the MATHEW/ADPIC models estimate the air concentrations of the tracer to within a factor of 2 of the measured values 20 to 50% of the time, and to within a factor of 5 about 35 to 85% of the time. The lower performance is during complex meteorological conditions or complex terrain, or elevated release heights. The higher performances is in simpler settings and shorter distances.

Part K: Model Usage Considerations		
K1	**Ease of Model Use**	**Training required to run the model:_4__ background (years of education)** **__ training time needed on the model to be able to exercise all model capabilities** Recommend minimum of BS in meteorology with knowledge of FORTRAN. **Training required to continue development of the model:** **_Min. 6 months_ background (years of education)** Recommend Ph. D. in atmospheric sciences. **_6 months_ training time needed on the model to be able to exercise all model capabilities** See above.
K2	**Time to Process From Notification of Release (including data acquisition) to Production of Product Listed in #K1, Listed for Platforms for Which the Program is Already Compiled**	When fully implemented with automated meteorological data acquisition on a workstation, the time to produce contour plots from when input files are completed is 2-5 min. See: Lawver, B.S., T.J. Sullivan, R.L. Baskett. 1993. A real-time monitoring/emergency response workstation using a 3-D numerical model initialized with sodar. American Nuclear Society Topical Meeting on Environment Transport and Dosimetry, ANS, Chicago. Also LLNL UCRL JC-113042.
K3	**Ease of Use of Output, Evaluated as the Time Needed to Train a College Graduate in the Use of the Output**	The ARAC plot format for the VAX/VMS version using GKS Graphics presents a contoured map of the user-specified consequences, associated health consequence description and appropriate source and timing labels. ARAC plots have been used by many emergency response managers for many years and are intended for interpretation without training.